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Original Article

The Clinical Impact of Advanced Age on the Postoperative Outcomes of Patients Undergoing Gastrectomy for Gastric Cancer: Analysis Across US Hospitals Between 2011–2017

David Uihwan Lee [1], **Gregory Hongyuan Fan**[2], **Kevin Chang**[2], **Ki Jung Lee**[2], **John Han**[2], **Daniel Jung**[2], **Jean Kwon**[2], **Raffi Karagozian**[2]

[1]Division of Gastroenterology and Hepatology, University of Maryland, Baltimore, MD, USA
[2]Liver Center, Division of Gastroenterology, Tufts Medical Center, Boston, MA, USA

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Correspondence to
David Uihwan Lee
Liver Center, Division of Gastroenterology and Hepatology, University of Maryland, 22 S Greene St, Baltimore, MD 21201, USA.
Email: dvleeman@gmail.com

ORCID iDs
David Uihwan Lee
https://orcid.org/0000-0001-7129-7532

Conflict of Interest
No potential conflict of interest relevant to this article was reported.

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ABSTRACT

Purpose: This study systematically evaluated the implications of advanced age on post-surgical outcomes following gastrectomy for gastric cancer using a national database.
Materials and Methods: The 2011–2017 National Inpatient Sample was used to isolate patients who underwent gastrectomy for gastric cancer. From this, the population was stratified into those belonging to the younger age cohort (18–59 years), sexagenarians, septuagenarians, and octogenarians. The younger cohort and each advanced age category were compared in terms of the following endpoints: mortality following surgery, length of hospital stay, charges, and surgical complications.
Results: This study included a total of 5,213 patients: 1,366 sexagenarians, 1,490 septuagenarians, 743 octogenarians, and 1,614 under 60 years of age. Between the younger cohort and sexagenarians, there was no difference in mortality (2.27 vs. 1.67%; P=0.30; odds ratio [OR], 1.36; 95% confidence interval [CI], 0.81–2.30), length of stay (11.0 vs. 11.1 days; P=0.86), or charges ($123,557 vs. $124,425; P=0.79). Compared to the younger cohort, septuagenarians had higher rates of in-hospital mortality (4.30% vs. 1.67%; P<0.01; OR, 2.64; 95% CI, 1.67–4.16), length of stay (12.1 vs. 11.1 days; P<0.01), and charges ($139,200 vs. $124,425; P<0.01). In the multivariate analysis, septuagenarians had higher mortality (P=0.01; adjusted odds ratio [aOR], 2.01; 95% CI, 1.18–3.43). Similarly, compared to the younger cohort, octogenarians had a higher rate of mortality (7.67% vs. 1.67%; P<0.001; OR, 4.88; 95% CI, 3.06–7.79), length of stay (12.3 vs. 11.1 days; P<0.01), and charges ($131,330 vs. $124,425; P<0.01). In the multivariate analysis, octogenarians had higher mortality (P<0.001; aOR, 4.03; 95% CI, 2.28–7.11).
Conclusions: Advanced age (>70 years) is an independent risk factor for postoperative death in patients with gastric cancer undergoing gastrectomy.

Keywords: Aged; Gastric cancer; Gastrectomy; Elderly; Geriatric medicine

Methodology: L.D.U., F.G.H., C.K., L.K., H.J., J.D., K.J., K.R.; Project administration: L.D.U.; Resources: L.D.U., F.G.H., C.K., L.K., H.J., J.D., K.J., K.R.; Software: L.D.U., F.G.H., C.K., L.K., H.J., J.D., K.J., K.R.; Supervision: L.D.U.; Validation: L.D.U., F.G.H., C.K., L.K., H.J., J.D., K.J., K.R.; Visualization: L.D.U., F.G.H., C.K., L.K., H.J., J.D., K.J., K.R.; Writing - original draft: L.D.U., F.G.H., C.K., L.K., H.J., J.D., K.J., K.R.; Writing - review & editing: L.D.U., C.K., L.K., H.J., J.D., K.J., K.R.

INTRODUCTION

In select patients with localized gastric tumors, gastrectomy may provide effective treatment [1-3], and in certain advanced cases, gastrectomy may be warranted to reduce the tumor burden for effective debulking, which can be followed by adjuvant chemotherapy and radiation methods [3-6]. Nonetheless, as gastrectomy can provide margin-free resection of tumor lesions [7,8], it remains a popular and viable option for select candidates with an amenable lesion anatomy and location [1,2,9].

However, since gastrectomy as a surgical procedure is invasive and carries significant operative risks [3,10], it is important that patients are risk-stratified and evaluated for their survivability and prognosis beforehand. Prior studies have defined several comorbidities and risk factors that impose a deterministic effect on outcomes [2,10]; However, complementary to the comorbidities, age is thought to have pronounced effects on postsurgical results [11-13] as it particularly relates to the natural physiological deterioration that occurs in the elderly, with reduced energy expenditure, slowed metabolism, slower healing mechanisms, sarcopenia and muscle loss, and reduced functional and ambulatory capacities, all of which undermine the recovery process and delay hospital discharge.

Therefore, we evaluated the clinical impact of advanced age as it pertains to senior populations (sexagenarians, septuagenarians, and octogenarians) undergoing gastrectomy for gastric cancer, using a national registry of hospital patients.

MATERIALS AND METHODS

National Inpatient Sample (NIS) database and variable selection

As in our previous studies, the NIS was used [14,15]. The NIS is a registry of data compiled from a stratified sample of the State Inpatient Database (SID), which is part of the Healthcare Cost and Utilization Project (HCUP). This is a conjoined effort by federal and state entities that is sponsored by the Agency for Healthcare Research and Quality (AHRQ). The data translated into the NIS were generated from billing data submitted to statewide data organizations from community hospitals. This process is conducted annually, and as a result, the NIS constitutes a 20% sample representative of all SID data from inpatient stays in non-federal hospitals (excluding rehabilitation and long-term acute care hospitals). The NIS is inclusive of weight data that facilitates the observation of trends over the years, as well as data on admission location, patient demographics, discharge, and hospital. In 2017, the NIS showed 7.2 million visits to 4,584 hospitals in 48 states, which accounts for 97% of the US population.

This study was based on NIS data from discharges between 2011–2017 [16,17]. The 2017 NIS included up to 40 diagnoses from the International Classification of Diseases (ICD) and 25 ICD Procedural Classification System (ICD-PCS) codes per patient [18]. From 2011 to 2017, the NIS experienced significant revision, including, a transition from the ninth edition of the ICD to the tenth, that is, ICD-9 to ICD-10, in 2015 [19]. In addition, in 2014, the NIS began to draw data as a systematic fraction of discharges from all hospitals rather than examining 100% of discharges from only 1,000 hospitals [20]. We accommodated these revisions according to the recommended guidelines.

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The ICD-9 and ICD-10 codes were used to select study variables from the database via a standardized protocol that effectively minimized heterogeneity [21-23]. The procedure involved the use of a preprogrammed search engine that identified specific ICD-9 and ICD-10 codes containing the searched keywords in the codes themselves or their descriptions. To accomplish this, the engine utilized the official ICD-9 and ICD-10 conversion tables and diagnosis-related group (DRG)-based mapping system set for either ICD-9 or ICD-10 [24-27]. The **Supplementary Table 1** comments on the list of ICD codes used for the analysis and their definitions.

Study cohort and study variables

This study cohort included patients undergoing gastric resection surgery, including interposition gastrectomy, partial gastrectomy, and total gastrectomy, for gastric cancer, as denoted by their NIS discharge diagnosis. Patients under the age of 18 years were excluded.

The exposure variable studied was advanced age, which was defined as being older than 60 years. The population was further divided into sexagenarian, septuagenarian, and octogenarian subgroups. The study endpoints included in-hospital outcomes such as mortality, length of stay, hospitalization charges, discharge disposition, and postoperative complications such as bleeding, infection, wound complications, and respiratory failure.

Study design and statistical analyses

Differences between the advanced and younger age populations were analyzed using univariate and multivariate methods. Univariate analysis was performed using Welch's and Student's t-tests or Fisher's exact or χ^2 tests, while multivariate analysis was performed sequentially with three models using logistic regression analyses, which allowed us to examine the significance of the study endpoints iteratively. Notably, the multivariate regression equations were integrated into the analysis of the following endpoints: postoperative mortality risk and surgical complications. In terms of each model configuration and covariates, Model 1 contained demographic variables, including age, race, and sex; Model 2 contained demographic variables and medical covariates, including diabetes, hyperlipidemia, hypertension, chronic obstructive pulmonary disease (COPD), coronary artery disease (CAD), chronic kidney disease (CKD), congestive heart failure (CHF), coagulopathy, alcohol use disorder, cigarette use, obesity, prevalence of elective vs. emergent procedure, gastric disorders (gastric ulcers, gastritis and duodenitis, and type of gastrectomy including total or partial gastrectomy), and cancer-related covariates (spread to lymph nodes, spread to non-gastrointestinal organs, spread to gastrointestinal organs, and chemotherapy history); Model 3 contained the aforementioned demographic variables and medical covariates, as well as patient socioeconomic-related covariates and hospital characteristics, including median household income, hospital bed size, hospital location/teaching status, hospital region, and insurance type. In the primary analysis, the multivariate regression outputs were expressed using Model 3 results, given that the final model involved a model with the most comprehensive set of covariates included in the regression equation. Given the comprehensiveness of the covariate list, the variance inflation factor (VIF) was pivotal in alerting the possibility of multicollinearity. This was performed for each model configuration and analyzed to limit the possibility of multicollinearity with each iteration. Significance was denoted by P-value <0.05.

Statistical analyses in this study were conducted using R Studio version 1.2.5042 with R code version 3.6.3. This study did not require the National Review Board or institutional approval, as its data were obtained from the NIS database.

RESULTS

Patient selection

The post-match gastrectomy cohorts contained 1,366 sexagenarians, 1,490 septuagenarians, and 743 octogenarians, each compared with 1,614 patients under the age of 60 years. In total, 5,213 patients were included, and **Fig. 1** shows the patient selection procedure used in this study.

Comparison of demographics and medical covariates

Table 1 shows the comparison of demographics and medical covariates between patients in the older age cohorts and those under the age of 60 years. The average ages of the younger (age <60 years) cohort and the sexagenarian, septuagenarian, and octogenarian cohorts were 49.6, 64.8, 74.5, and 83.5 years, respectively. In general, cohorts belonging to the advanced age categories (sexagenarians, septuagenarians, and octogenarians) were more likely to be male and were more likely to be either White or Pacific Islanders. In addition, those in the advanced age cohorts were more likely to undergo partial gastrectomy than total resection. Other cohort comparisons in terms of baseline characteristics are shown in **Table 1**.

Comparison of hospital outcomes and complications

Tables 2-4 demonstrates the hospital outcomes for patients undergoing gastrectomy in the sexagenarian, septuagenarian, and octogenarian cohorts compared with those in the younger cohort. In the comparison between sexagenarians and the younger cohort, there was no difference in the primary outcomes, including mortality, length of stay, or hospitalization; however, the sexagenarians experienced higher rates of wound complications (2.49% vs. 1.18%; P=0.01; odds ratio [OR], 2.14; 95% confidence interval [CI], 1.22–3.77). Otherwise, there were no differences in other complication rates, including bleeding, infection, or respiratory failure. Those in the sexagenarian cohort were more frequently discharged to non-routine dispositions, including rehabilitation facilities and home health services. In multivariate analysis, sexagenarians continued to experience higher rates of postoperative wound complications (P=0.007; adjusted odds ratio [aOR], 2.28; 95% CI, 1.25–4.15) despite adjusting for confounders.

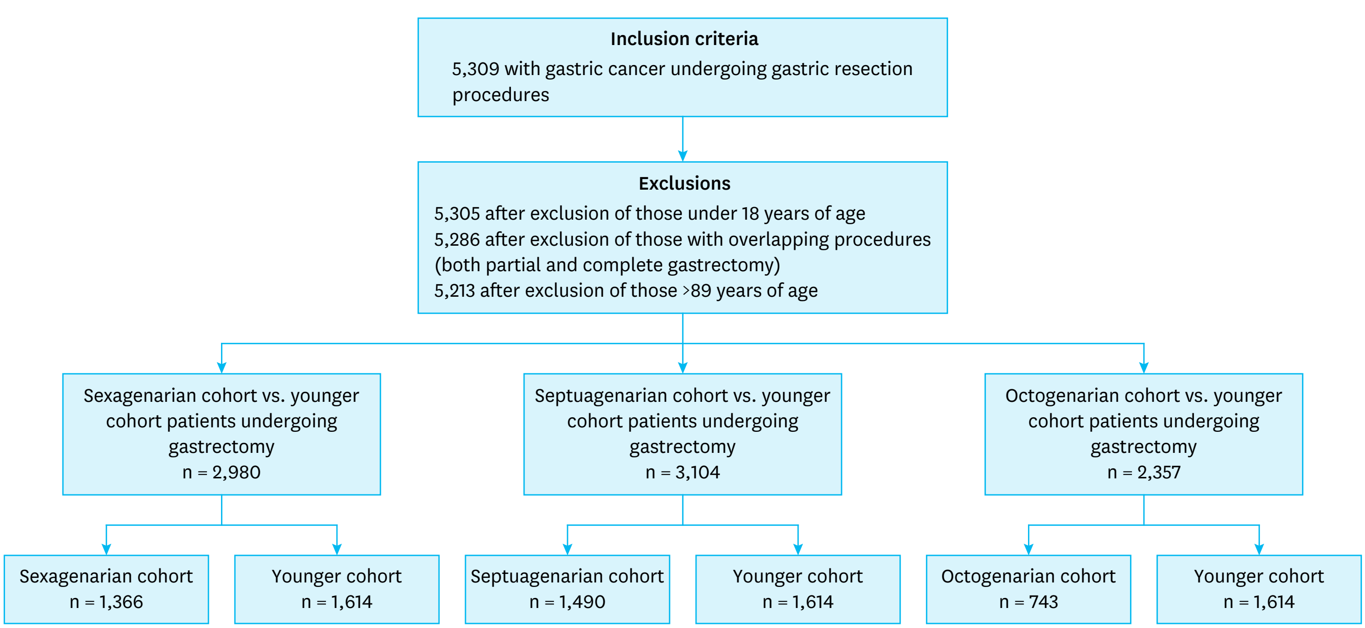

Fig. 1. This figure demonstrates the patient selection procedure of the study.

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Table 1. Comparison of patient demographics and medical covariates between younger (age <60) versus older cohorts; those undergoing gastrectomy

Demographics	Younger patients	Sexagenarians		Septuagenarians		Octogenarians	
	n = 1,614	n = 1,366	P-value	n = 1,490	P-value	n = 743	P-value
Age (median years)	49.60	64.80	<0.001	74.50	<0.001	83.50	<0.001
Sex: Female (%)	47.40	42.70	0.011	42.40	0.006	44.30	0.170
Race (%)			<0.001		<0.001		<0.001
White	37.80	45.40		51.70		61.80	
Black	22.40	21.70		19.10		14.10	
Hispanic	22.90	15.50		13.90		10.60	
Asian or Pacific Islander	10.70	11.40		10.90		8.88	
Native American	0.93	0.80		0.40		0.27	
Other	5.27	5.12		4.09		4.31	
Medical comorbidities (%)							
Diabetes	13.90	27.00	<0.001	31.80	<0.001	30.60	<0.001
Hyperlipidemia	9.54	16.80	<0.001	19.30	<0.001	19.00	<0.001
Hypertension	31.50	51.50	<0.001	58.30	<0.001	57.70	<0.001
Chronic obstructive pulmonary disease	3.59	8.13	<0.001	11.30	<0.001	14.00	<0.001
Coronary artery disease	5.20	11.20	<0.001	21.70	<0.001	26.00	<0.001
Chronic kidney disease	3.35	5.86	0.001	12.00	<0.001	15.50	<0.001
Congestive heart failure	1.86	4.32	<0.001	9.93	<0.001	14.30	<0.001
Coagulopathy	0.68	0.44	0.530	0.74	1.000	0.40	0.570
Alcohol use disorder	3.28	1.83	0.018	1.28	<0.001	0.14	<0.001
Cigarette use	28.60	31.60	0.083	29.30	0.670	27.50	0.610
Obesity	6.44	6.66	0.870	6.17	0.810	5.65	0.520
Elective (vs. emergent) procedure	75.90	77.60	0.290	76.40	0.750	70.00	0.003
Gastric disorders (%)							
Gastric ulcer	6.38	5.71	0.490	3.89	0.002	5.11	0.270
Gastritis and duodenitis	6.94	6.15	0.430	5.57	0.130	5.11	0.110
Type of gastrectomy (%)							
Total gastrectomy	36.70	32.30	0.012	28.10	<0.001	18.80	<0.001
Partial gastrectomy	63.30	67.70	0.012	71.90	<0.001	81.20	<0.001
Cancer-related (%)							
Spread to lymph nodes	24.00	23.60	0.870	21.90	0.190	23.30	0.750
Spread to gastrointestinal organs	16.00	12.20	0.004	10.00	<0.001	8.75	<0.001
Spread to non-gastrointestinal organs	5.20	4.03	0.150	2.75	<0.001	3.10	0.029
Chemotherapy history	9.91	10.30	0.760	7.25	0.010	2.56	<0.001

In the comparison between the septuagenarians and the younger cohort, septuagenarians exhibited higher mortality rates (4.30% vs. 1.67%; P<0.001; OR, 2.64; 95% CI, 1.67–4.16), as well as a greater length of stay (12.1 vs 11.1 days; P<0.001) and charges ($139,200 vs. $124,425; P<0.001). Those assigned to the septuagenarian cohort were more frequently discharged for non-routine dispositions, including rehabilitation facilities and home health services. In terms of surgical complications, septuagenarians displayed higher rates of respiratory failure (5.17% vs. 2.66%; P<0.001; OR, 1.99; 95% CI, 1.36–2.91); however, there was no significant difference in other complications, including bleeding, infections, or wound complications. In the multivariate analysis, septuagenarians continued to demonstrate higher rates of postoperative death (P=0.01; aOR, 2.01; 95% CI, 1.18–3.43) despite controlling for covariates.

In the comparison between octogenarians and the younger cohort, octogenarians exhibited higher rates of postoperative mortality (7.67% vs. 1.67%; P<0.001; OR, 4.88, 95% CI, 3.06–7.79), as well as a greater length of stay (12.3 vs. 11.1 days; P<0.001) and charges ($131,330 vs. $124,425; P<0.001). Those assigned to the octogenarian cohort were more frequently discharged for non-routine dispositions, including rehabilitation facilities and home health services. In terms of postoperative complications, octogenarians experienced higher rates of respiratory failure (4.58% vs. 2.66%; P=0.021; OR, 1.75; 95% CI, 1.11–2.77); however, there was no difference in the risk of bleeding, infections, or wound complications.

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Table 2. Comparison of patient outcomes between younger (age <60) versus sexagenarian cohorts; those undergoing gastrectomy

Hospital outcomes	Sexagenarians	Younger patients		Univariate analysis		Multivariate analysis		
	n = 1,366 (45.84%)	n = 1,614 (54.16%)	P-value	OR	95% CI	aOR	95% CI	P-value
Mortality (%)	2.27	1.67	0.300	1.36	(0.81–2.30)	1.18	(0.67–2.11)	0.563
Length of stay (days)	11.00	11.10	0.860					
Hospitalization costs ($)	123,557.00	124,425.00	0.790					
Disposition at discharge (%)			<0.001					
Routin	60.20	69.80						
Short-term hospital	0.59	0.43						
Skilled nursing or other facility	9.30	4.15						
Home health care	27.30	23.90						
Against medical advice	0.29	0.12						
Died	2.27	1.67						
Unknown	0.00	0.00						
Postoperative complications (%)								
Postoperative bleeding	2.42	2.73	0.680	0.88	(0.56–1.40)	0.85	(0.53–1.39)	0.526
Postoperative infection	3.73	3.66	0.990	1.02	(0.70–1.50)	1.21	(0.80–1.83)	0.368
Postoperative wound complications	2.49	1.18	0.010	2.14	(1.22–3.77)	2.28	(1.25–4.15)	0.007
Postoperative respiratory failure	2.64	2.66	1.000	0.99	(0.63–1.55)	0.77	(0.48–1.25)	0.293

OR = odds ratio; CI = confidence interval; aOR = adjusted odds ratio.

Table 3. Comparison of patient outcomes between younger (age <60) versus septuagenarian cohorts; those undergoing gastrectomy

Hospital outcomes	Septuagenarians	Younger patients		Univariate analysis		Multivariate analysis		
	n = 1,490 (48.00%)	n = 1,614 (52.00%)	P-value	OR	95% CI	aOR	95% CI	P-value
Mortality (%)	4.30	1.67	<0.001	2.64	(1.67–4.16)	2.01	(1.18–3.43)	0.010
Length of stay (days)	12.10	11.10	0.002					
Hospitalization costs ($)	139,200.00	124,425.00	<0.001					
Disposition at discharge (%)			<0.001					
Routine	43.60	69.80						
Short-term hospital	0.94	0.43						
Skilled nursing or other facility	20.10	4.15						
Home health care	30.90	23.90						
Against Medical Advice	0.07	0.12						
Died	4.30	1.67						
Unknown	0.07	0.00						
Postoperative complications (%)								
Postoperative bleeding	2.35	2.73	0.580	0.86	(0.55–1.35)	0.89	(0.53–1.48)	0.645
Postoperative infection	4.03	3.66	0.660	1.11	(0.77–1.60)	1.12	(0.73–1.72)	0.593
Postoperative wound complications	1.54	1.18	0.470	1.32	(0.71–2.43)	1.62	(0.80–3.29)	0.180
Postoperative respiratory failure	5.17	2.66	<0.001	1.99	(1.36–2.91)	1.34	(0.86–2.08)	0.195

OR = odds ratio; CI = confidence interval; aOR = adjusted odds ratio.

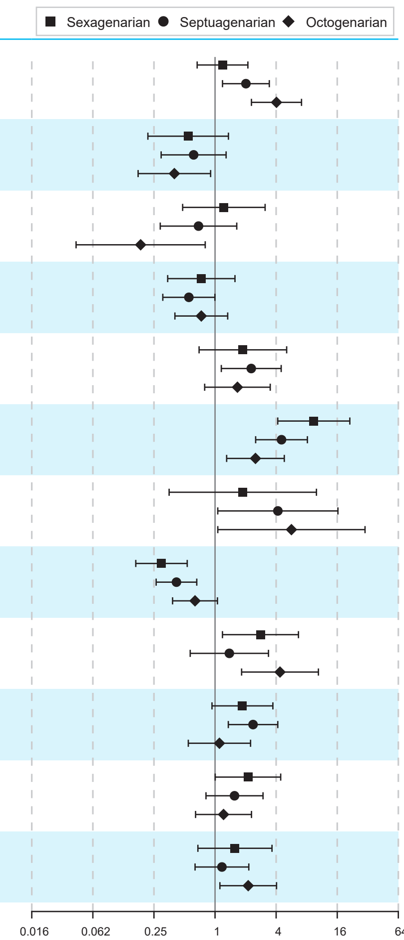
Table 4. Comparison of patient outcomes between younger (age <60) versus octogenarian cohorts; those undergoing gastrectomy

Hospital outcomes	Octogenarians	Younger patients		Univariate analysis		Multivariate analysis		
	n = 743 (31.52%)	n = 1,614 (68.48%)	P-value	OR	95% CI	aOR	95% CI	P-value
Mortality (%)	7.67	1.67	<0.001	4.88	(3.06–7.79)	4.03	(2.28–7.11)	<0.001
Length of stay (days)	12.30	11.10	<0.001					
Hospitalization costs ($)	131,330.00	124,425.00	<0.001					
Disposition at discharge (%)			<0.001					
Routine	29.90	69.80						
Short-term hospital	0.94	0.43						
Skilled nursing or other facility	33.80	4.15						
Home health care	27.70	23.90						
Against medical advice	0.00	0.12						
Died	7.67	1.67						
Unknown	0.00	0.00						
Postoperative complications (%)								
Postoperative bleeding	2.56	2.73	0.920	0.94	(0.54–1.62)	1.06	(0.56–2.00)	0.852
Postoperative infection	3.10	3.66	0.570	0.84	(0.52–1.37)	0.87	(0.48–1.56)	0.633
Postoperative wound complications	1.08	1.18	1.000	0.91	(0.40–2.10)	1.29	(0.48–3.42)	0.615
Postoperative respiratory failure	4.58	2.66	0.021	1.75	(1.11–2.77)	1.16	(0.67–2.00)	0.604

OR = odds ratio; CI = confidence interval; aOR = adjusted odds ratio.

Multivariate model of postoperative mortality in sexagenarian vs. septuagenarian vs. octogenarian patients undergoing gastrectomy

Variable	Comparator Group	aOR	95% CI	P-value
Sexagenarians	Sexagenarian	1.185	0.666 - 2.107	0.563
Septuagenarians	Septuagenarian	2.014	1.185 - 3.426	0.010
Octogenarians	Octogenarian	4.031	2.284 - 7.114	< 0.001
Hispanic (vs. White)	Sexagenarian	0.543	0.218 - 1.355	0.191
	Septuagenarian	0.615	0.294 - 1.286	0.196
	Octogenarian	0.397	0.174 - 0.904	0.028
Asian or Pacific Islander (vs. White)	Sexagenarian	1.222	0.479 - 3.114	0.674
	Septuagenarian	0.687	0.288 - 1.636	0.397
	Octogenarian	0.185	0.043 - 0.800	0.024
Diabetes	Sexagenarian	0.733	0.341 - 1.572	0.424
	Septuagenarian	0.552	0.306 - 0.997	0.049
	Octogenarian	0.732	0.402 - 1.332	0.307
Chronic Kidney Disease	Sexagenarian	1.880	0.696 - 5.079	0.213
	Septuagenarian	2.274	1.153 - 4.485	0.018
	Octogenarian	1.662	0.790 - 3.498	0.180
Congestive Heart Failure	Sexagenarian	9.399	4.149 - 21.292	< 0.001
	Septuagenarian	4.519	2.513 - 8.128	< 0.001
	Octogenarian	2.502	1.301 - 4.812	0.006
Coagulopathy	Sexagenarian	1.877	0.353 - 9.986	0.460
	Septuagenarian	4.159	1.064 - 16.260	0.040
	Octogenarian	5.658	1.064 - 30.074	0.042
Elective Admission	Sexagenarian	0.297	0.166 - 0.532	< 0.001
	Septuagenarian	0.416	0.263 - 0.660	< 0.001
	Octogenarian	0.635	0.382 - 1.056	0.080
Spread to Non-Gastrointestinal Organs	Sexagenarian	2.803	1.183 - 6.638	0.019
	Septuagenarian	1.383	0.569 - 3.361	0.474
	Octogenarian	4.367	1.827 - 10.436	< 0.001
Spread to Gastrointestinal Organs	Sexagenarian	1.862	0.933 - 3.715	0.078
	Septuagenarian	2.368	1.351 - 4.151	0.003
	Octogenarian	1.105	0.545 - 2.238	0.783
Household Income Quartile 3 (vs. Quartile1)	Sexagenarian	2.110	1.004 - 4.436	0.049
	Septuagenarian	1.555	0.814 - 2.970	0.181
	Octogenarian	1.213	0.643 - 2.287	0.551
Hospital Region South (vs. Northeast)	Sexagenarian	1.571	0.678 - 3.641	0.292
	Septuagenarian	1.169	0.635 - 2.151	0.616
	Octogenarian	2.123	1.116 - 4.036	0.022



*Variables with non-significant correlations were excluded from the model

Fig. 2. This figure demonstrates the combined multivariate forest plot of patients with gastric cancer undergoing gastrectomy, using postsurgical morality as the primary endpoint and age-stratified cohorts as the primary exposures for the regression equation; additional covariates are listed in the forest plot.
aOR = adjusted odds ratio; CI = confidence interval.

In the multivariate analysis, octogenarians continued to exhibit higher rates of postoperative mortality (P<0.001; aOR, 4.03; 95% CI, 2.28–7.11) despite controlling for covariates. The combined forest plot that accumulated the individual age-stratified regression model is shown in **Fig. 2.** In this figure, the primary endpoint was postoperative death, and the independent variables included age-stratified exposures (advanced age categories) compared to the younger cohort group.

Supplementary analyses

Additional complementary analysis was performed to determine the descriptive significance of the baseline characteristics, including the patients' socioeconomic and hospital backgrounds. The results of the analysis are presented in **Supplementary Table 2**. **Supplementary Table 3** displays the configurations of the multivariate model iterations (including the non-final configurations), whereas **Supplementary Table 4** shows the VIF outputs of the individual model iterations. As VIF signifies the quotient of the variance that includes a multidimensional comparison of the regression-included terms, thereby estimating the possibility of multicollinearity, a smaller output value equates to a lower possibility of multicollinearity in the variable set. In the current VIF iterations, for all age-stratified regression models, the VIF values

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are typically within the range of 1–2, which denotes a minimalized effect of multicollinearity in the equations, despite the delineations of the covariates.

DISCUSSION

With the stratification of age groups, this study demonstrated a trend of increasing mortality risk ratios with age, delineating a positive correlation between the operative as well as postoperative risks of gastrectomy and increasing age. The septuagenarian and octogenarian groups also had longer lengths of stay and higher healthcare costs. In terms of postoperative complications, the sexagenarian cohort had a higher rate of wound complications, whereas the septuagenarian and octogenarian cohorts had a higher rate of respiratory failure. These results were derived from a large sample size using the National Inpatient Sample database. Propensity score matching and post-regression analysis were conducted with the inclusion of preselected sets of medical covariates to minimize the presence of confounding factors, thus improving the power of the statistical analysis.

This study validates previous results demonstrating higher postoperative mortality in the elderly with increasing age [28-31]. In terms of complications, studies have historically yielded mixed results regarding the role of age in the risk of postoperative wound complications [32-34]. For instance, Kaye et al. showed the role of age to be more complicated, with the risk of wound complications peaking at age 65 years [35]. This seems to be congruent with our results, which demonstrated elevated wound complications only in the sexagenarian cohort. Complex effects of age also manifest in respiratory failure rates [36-38], which our study found to be elevated in the septuagenarian and octogenarian groups. While specific postoperative outcomes pertaining to each decade group may require further study, the age-stratified approach of our study revealed that the septuagenarian group is the cut-off at which significant increases in mortality, length of hospital stay, and hospital charges begin to occur.

Notably, there is a trend for increasing rates of emergency surgery and partial gastrectomy with increasing age. We postulate that this trend arises from the differences in the phenotypic manifestations of gastric cancer observed between different age groups, with the elderly population experiencing a more dire, metastatic, and aggressive tumor formation that requires emergent surgery due to anatomical and obstructive complications [39-41]. Additionally, partial gastrectomy (in contrast to total gastrectomy) is generally preferred in the elderly population because of its reduced invasiveness [40,42,43].

With increasing age, the human body has a gradual decline in organ function and in the ability to maintain homeostasis. Aging bodies have a declining rate of metabolism and energy expenditure, resulting in a smaller reserve of physiological energy. When met with overwhelming external stress, such as undergoing gastrectomy, the reservoir is exhausted, leading to decompensation and an increased risk of mortality [44,45]. A reduction in the responsiveness of the autonomic nervous system leads to poorer cardiac output in response to stress [46]. Furthermore, cardiac function in the elderly is undermined by a decrease in ventricular compliance, which decreases ejection fraction under stress [47,48]. It is possible that the presence of increased respiratory failure also contributes to increased postoperative mortality, and a higher risk of postoperative respiratory failure can be attributed to altered pulmonary function due to aging. Anatomically, the degeneration of elastic fibers leads

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to decreased surface area and compliance of the lungs as well as thoracic and chest wall deformities, making breathing difficult in the elderly population. Sarcopenic changes in the elderly lead to decreased respiratory muscle strength and further reduce pulmonary function, resulting in a higher risk of mortality [44,49-51]. It is also possible that the use of anesthetic agents contributes to worse postoperative outcomes in elderly patients. Anesthetic agents depress beta-adrenergic and baroreceptor reflexes in the cardiovascular system, which further impairs compensatory mechanisms in response to hypotension, leading to a higher risk of complications and mortality [52,53]. However, as noted in the multivariate analysis, these pulmonary function-altering mechanisms may be accounted for by a set of intrinsic components, such as underlying lung capacity and ventilatory mechanics, that are affected by restrictive/obstructive diseases (i.e., COPD). Hence, while the operative complications were demonstrable in the univariate analysis, after adjusting for these individual debilitating cardiopulmonary disorders, the relationship between advanced age categories and respiratory failure was not significant.

This study demonstrated the negative impact of age on the outcomes of patients who underwent gastrectomy for gastric cancer, specifically beginning in the 7th decade of life. Despite the lack of consensus on the cutoff age for gastrectomy, this study reaffirms the importance of implementing a risk-benefit analysis to assess postoperative outcomes in the elderly population. If the analysis produces favorable results and the patient undergoes gastrectomy, respiratory function should be closely monitored perioperatively due to the increased risk of respiratory failure in this population. The care team should also consider risk reduction strategies to target possible postoperative pulmonary complications and maintain respiratory system functionality. Adopting such strategies will also help decrease healthcare charges [54].

The limitation of the study relates to the fact that there is no biochemical or biomarker information available to demonstrate the laboratory differences between cases and controls. The lack of such information limits the evaluation of laboratory-specific calculations that pertain to the postoperative conditions (for example, Clavien–Dindo classifications); nevertheless, to recompense for this deficit, surrogate surgical complications as compiled aggregates of ICD-9/10 codes were used to demonstrate the operative risks associated with each comparison. Furthermore, the NIS does not contain information beyond hospital discharge; thus, operative complications and surgical events are limited to the time point of hospital discharge. In line with this, further studies with prospective post-discharge information are warranted to follow-up on the current observations.

In conclusion, this study found advanced age to be an independent risk factor for postoperative mortality in patients with gastric cancer undergoing gastrectomy.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

ICD-9 and ICD-10 codes

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Supplementary Table 2

Comparison of patient socioeconomic status and hospital characteristics between younger (age <60) versus older cohorts; those undergoing gastrectomy

Click here to view

Supplementary Table 3

Comparison of patient outcome between younger (age <60) versus older (age 60+) cohorts; those undergoing gastrectomy

Click here to view

Supplementary Table 4

VIF analyses for multivariate models of patient outcomes following gastrectomy

Click here to view

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